Section 6
Environmental Control and Life Support System Overview

6.1 Introduction

The Environmental Control and Life Support System (ECLSS) maintains a pressurized habitable environment, provides water recovery and storage, and provides fire detection and suppression within the International Space Station (ISS). This segment presents an overview of ECLSS and its component subsystems. It also describes the relations between subsystems, and between ECLSS and other Station systems.

6.2 Objectives

After completing this section, you should be able to

- Describe the major functions and general functional redundancies provided by ECLSS and each of its subsystems.
- Identify major ECLSS hardware components and state their function.
- Identify ECLSS intrasystem and intersystem interfaces.
- Describe major responsibilities and milestones of the United States Orbital Segment (USOS) and Russian Orbital Segment (ROS) up through 8A, as well as the USOS added capabilities at Assembly Complete.

6.3 ECLSS Overview

The Environmental Control and Life Support System (ECLSS) provides a pressurized and habitable environment within the Space Station by supplying correct amounts of oxygen and nitrogen, controlling the temperature and humidity, removing carbon dioxide and other atmospheric contaminants, and monitoring the atmosphere for the presence of combustion products, as well as major constituent proportions. The system also collects, processes, and stores water and waste used and produced by the crewmembers. Fire suppression and crew safety equipment are provided.

These general functions of the five major subsystems of USOS ECLSS at Flight 8A are shown in Figure 6-1. As illustrated, the primary ECLSS concern, whether directly or indirectly, is with the ISS atmosphere. This manual presents ECLSS through its subsystems, starting with Atmosphere Control and Supply (ACS), then Atmosphere Revitalization (AR), Temperature and Humidity Control (THC), Fire Detection and Suppression (FDS), and finally Water Recovery and Management (WRM).

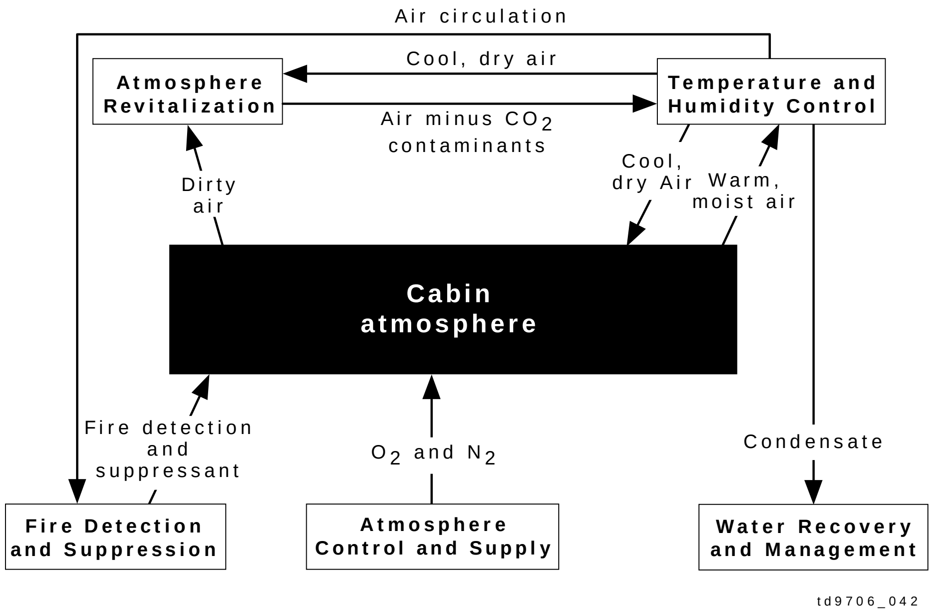

Figure 6-1. ECLSS Subsystem interfaces at Flight 8A

6.3.1 Atmosphere Control and Supply

In Figure 6-2, the USOS Atmosphere Control and Supply (ACS) Subsystem and its interfaces are illustrated for a Flight 8A configuration. ACS provides oxygen and nitrogen to maintain the Space Station atmosphere at the correct pressure and composition for human habitation. ACS also provides gas support to various users on the Station, as well as pressure equalization and depressurization capabilities.

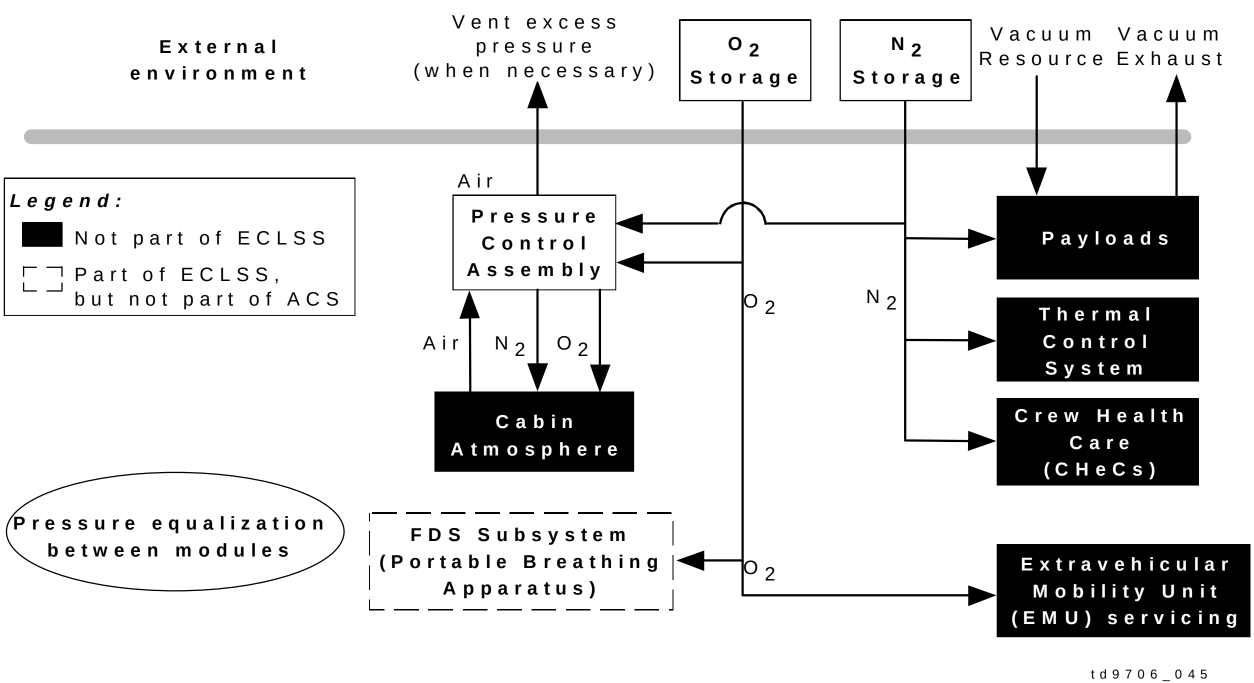

Figure 6-2. Atmosphere Control and Supply Subsystem at Flight 8A

6.3.1.1 ROS Supply and Control

The Russian Orbital Segment (ROS) has primary responsibility for atmosphere control and supply functions at the Flight 8A configuration.. The Progress resupply vehicle is outfitted with tanks that can be filled with either nitrogen, air, or oxygen. These tanks are manually opened by the crew if the cabin pressure is low. Oxygen for the Station is primarily supplied by an oxygen generator called the Elektron, which electrolyzes water into hydrogen and oxygen. The oxygen flows into the cabin atmosphere, while the hydrogen is vented overboard. Additional oxygen is provided by a Solid Fuel Oxygen Generator ( ) that uses chemical cartridges to produce oxygen in an exothermic reaction.

6.3.1.2 USOS Supply, Distribution, and Control

The oxygen and nitrogen gases used by the USOS ACS Subsystem are provided through the supply, distribution, and control portions of the subsystem. Four high-pressure gas tanks, two of nitrogen and two of oxygen, are stored on the exterior of the Airlock. The gases are distributed to the various users by a plumbed system running throughout the USOS. Another system of high-pressure plumbing allows the tanks to be recharged by the shuttle. The Oxygen Recharge Compressor Assembly (ORCA) housed in the Airlock enables the oxygen tanks to be fully recharged; the shuttle does not store oxygen at high enough pressure to fully recharge the tanks. Empty tanks can also be swapped out with full tanks as a second resupply option.

The Pressure Control Assembly (PCA) monitors atmospheric pressures, controls the introduction of nitrogen and oxygen into the cabin atmosphere, and provides the means to depressurize Station volumes if required. The depressurization function, used in both standard operations and in emergencies, is provided by a subassembly of the PCA called the Vent and Relief Assembly (VRA).

6.3.1.3 User Support

ACS provides gas support to several users on the Station besides the atmosphere. Nitrogen from ACS is used to pressurize the Internal Thermal Control System accumulators and to calibrate the Crew Health Care System Volatile Organic Analyzer. The biggest users of nitrogen resources are the Payloads. A minor subsystem of ECLSS, the Vacuum System, is included with ACS because its Payload support functions are similar to those of ACS. Where ACS provides nitrogen to Payload users, the Vacuum System provides vacuum resource and exhaust. Oxygen is provided for Extravehicular Activities (EVAs), and to the Fire Detection and Suppression (FDS) Portable Breathing Apparatus (PBA). An Airlock Depressurization Pump is also part of normal EVA activities.

6.3.1.4 Manual Pressure Equalization Valves

The ACS Subsystem also provides Manual Pressure Equalization Valves (MPEVs) to equalize pressure between Space Station modules. A valve on each hatch permits pressure equalization as modules are added to the Station, during normal EVA activities, or in the event that a module has been isolated in a contingency procedure.

6.3.1.5 Added ACS Capabilities at Assembly Complete

Figure 6-3 is similar to Figure 6-2, but it depicts an Assembly Complete configuration of the subsystem. At Assembly Complete, the ACS Subsystem will have the addition of an Oxygen Generator Assembly (OGA) on the USOS, and a device called a Sabatier on the ROS. The Sabatier conserves Station resources by producing water through reaction of hydrogen from the Elektron with carbon dioxide from the Atmosphere Revitalization Subsystem. At Assembly Complete, ACS will also provide oxygen to the WRM Subsystem Potable Water Processor.

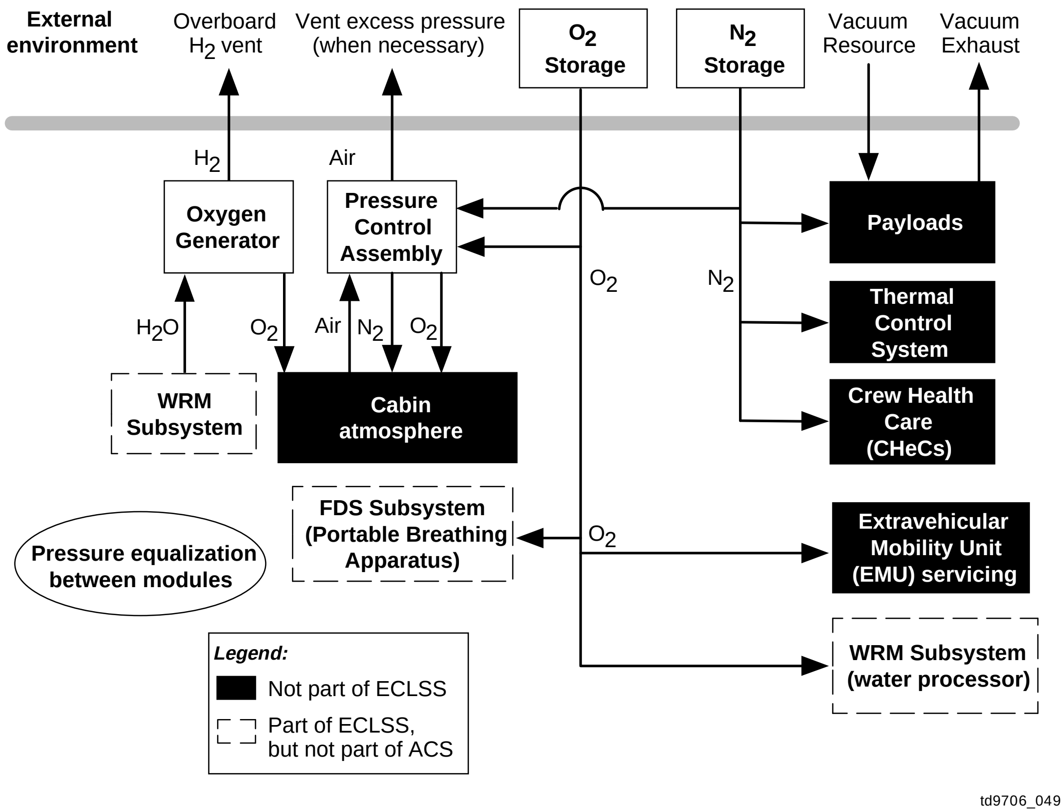

Figure 6-3. ACS Subsystem at Assembly Complete

6.3.2 Atmosphere Revitalization

Figure 6-4 shows the USOS Atmosphere Revitalization (AR) Subsystem and its interfaces. The AR Subsystem ensures that the atmosphere provided by the Atmosphere Control and Supply (ACS) Subsystem remains safe and pleasant to breathe. AR performs carbon dioxide removal, trace contaminant control, and major atmospheric constituent monitoring.

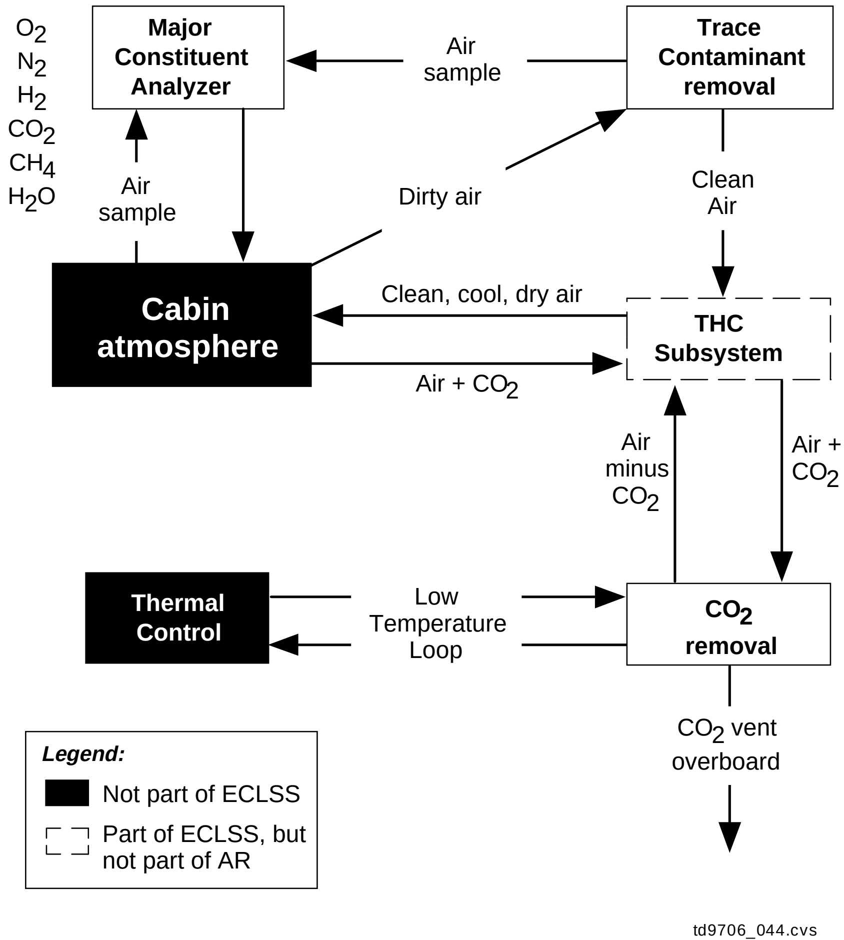

Figure 6-4. Atmosphere Revitalization Subsystem

6.3.2.1 Major Constituent Analyzer and Sample Delivery System

The Major Constituent Analyzer (MCA) monitors the composition of the Station atmosphere. Measurements are used to control the addition of oxygen and indirectly, nitrogen, into the Station atmosphere by the ACS Subsystem, and to monitor the performance of the assembly that removes carbon dioxide. Gas Analyzers, using several different gas detection methods, provide similar functions on the ROS. Air is delivered to the MCA by a network of pipes, valves, and sample ports running throughout the USOS. This network is called the Sample Delivery System (SDS).

6.3.2.2 Carbon Dioxide Removal

The Carbon Dioxide Removal Assembly (CDRA) collects carbon dioxide from the cabin atmosphere with a series of sorbent beds and expels the unwanted gases to space. On the ROS, a device called the Vozdukh provides the same function; lithium hydroxide-based canisters are available for backup functionality.

6.3.2.3 Trace Contaminant Control

The Trace Contaminant Control Subassembly (TCCS) filters and catalyzes numerous gaseous contaminants and odors from the cabin atmosphere. These contaminants might be caused by material off-gassing, leaks, spills, or other means. A Trace Contaminant Control Unit ( ) similar to the TCCS and a Harmful Impurities Filter ( ) provide contaminant control for the ROS.

6.3.2.4 Added AR Capabilities at Assembly Complete

At Assembly Complete, the USOS adds duplicates of each of the MCA, CDRA, and TCCS. These duplicates will serve as backup only, since each device operates at a three-person rate, and the ROS has similar capabilities used in conjunction with the USOS.

6.3.3 Temperature and Humidity Control

Figure 6-5 shows the USOS Temperature and Humidity Control (THC) Subsystem and its interfaces. THC helps maintain a habitable environment by circulating air, removing humidity, and maintaining the temperature of the Station atmosphere. Circulation of the atmosphere minimizes temperature variations, ensures homogeneous atmospheric composition, and provides a vehicle for smoke detection. Three levels of circulation are provided: rack, intramodule, and intermodule ventilation. Rack ventilation cools and circulates air within an individual rack. Intramodule ventilation provides cooling and humidity removal, as well as circulation to ensure a consistent atmosphere within a single module. Finally, intermodule ventilation circulates air between modules to ensure a homogeneous atmosphere throughout the Station. While the ROS equivalent of THC equipment is considered a part of the ROS Thermal Control System, it is functionally very similar to the USOS equipment.

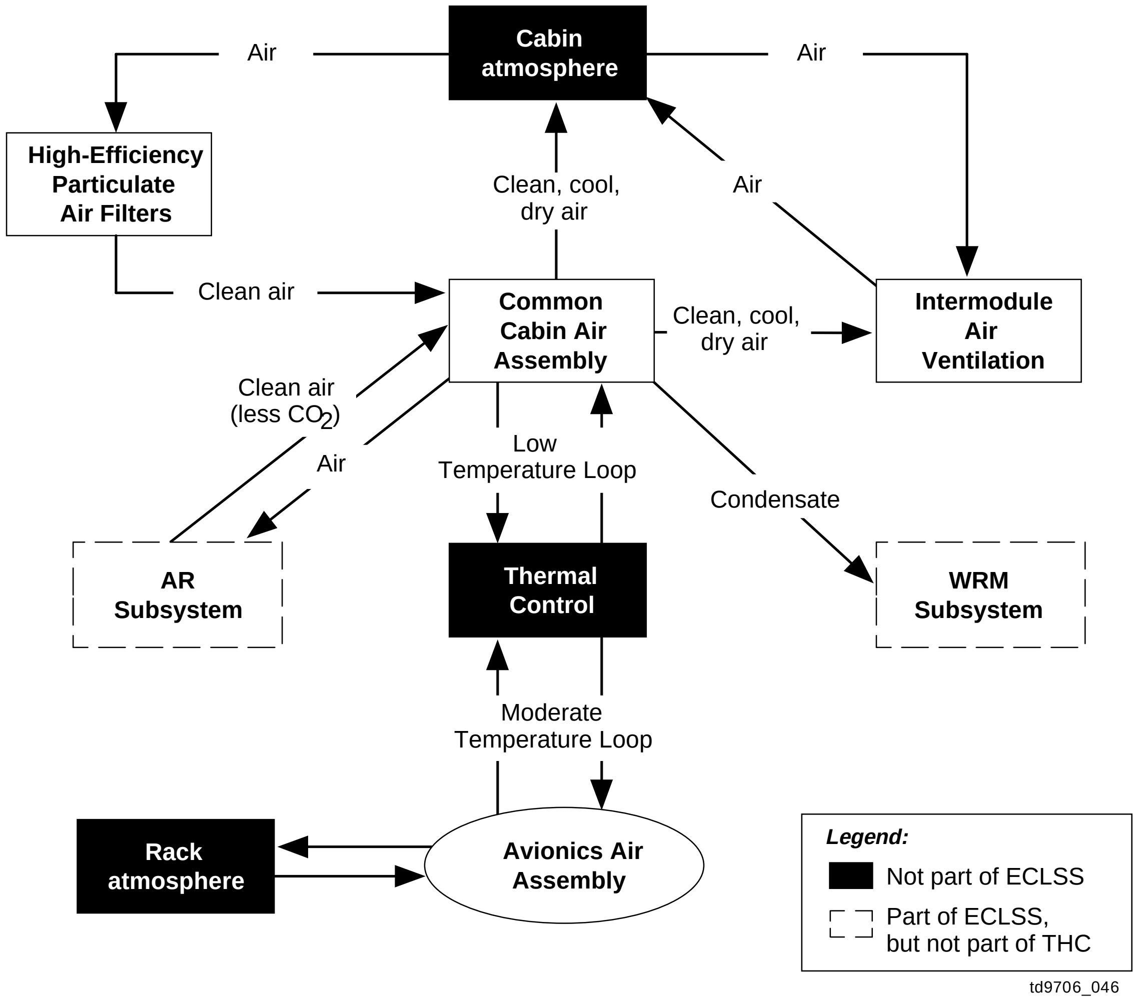

Figure 6-5. Temperature and Humidity Control Subsystem

6.3.3.1 Common Cabin Air Assembly

The Common Cabin Air Assembly (CCAA) provides intramodule ventilation, temperature control, and humidity removal. Air is pulled from the atmosphere through High Efficiency Particulate Air (HEPA) filters, pushed across a condensing heat exchanger, and returned to the Lab atmosphere through diffusers. Just as the Atmosphere Revitalization Subsystem removes gaseous contaminants from the atmosphere, HEPA filters remove particles and bacteria from the atmosphere. Moisture in the Station atmosphere is condensed by the heat exchanger and removed by a Water Separator (WS). The water removed is sent to the WRM Subsystem, while the conditioned air is supplied to the Station environment. ***There are two CCAAs in the U.S. Lab, of which only one is normally in operation at Flight 8A. There is also a CCAA in the Airlock which is only used during EVA operations.*** A Cabin Air Fan like that in the CCAA circulates air within Node 1.

6.3.3.2 Intermodule Ventilation

The Intermodule Ventilation (IMV) Assembly is comprised of several fans, diffusers, valves, and ducts that circulate air between modules. Hard plumbed supply and return ducts are located at most hatches on the USOS, and the hatches themselves can also act as circulation paths. The ROS relies on drag-through flexible ducting and open hatches for intermodule ventilation.

6.3.3.3 Avionics Air Assembly

The Avionics Air Assembly (AAA) is used to cool and circulate air within a specific rack volume. A fan and sensible (non-condensing) heat exchanger provide cooling for rack equipment and circulation for operation of the Fire Detection and Suppression Subsystem Smoke Detectors.

6.3.3.4 Added THC Capabilities at Assembly Complete

At Assembly Complete, additional CCAAs will be manifested in Node 2 and the Hab, as will IMV equipment for all modules. AAAs will be manifested as rack equipment requires.

6.3.4 Fire Detection and Suppression

The Fire Detection and Suppression (FDS) Subsystem provides smoke detection sensors for the Station volumes, fire extinguishers, and a system of alarms and automatic software responses to a fire event. Figure 6-6 shows the USOS FDS Subsystem and its interfaces. Following a fire, the Atmosphere Revitalization and Temperature and Humidity Control (THC) Subsystems remove the contaminants from the affected volume, or in an extreme case, the affected volume may have to be depressurized to extinguish the fire and/or exhaust the contaminants.

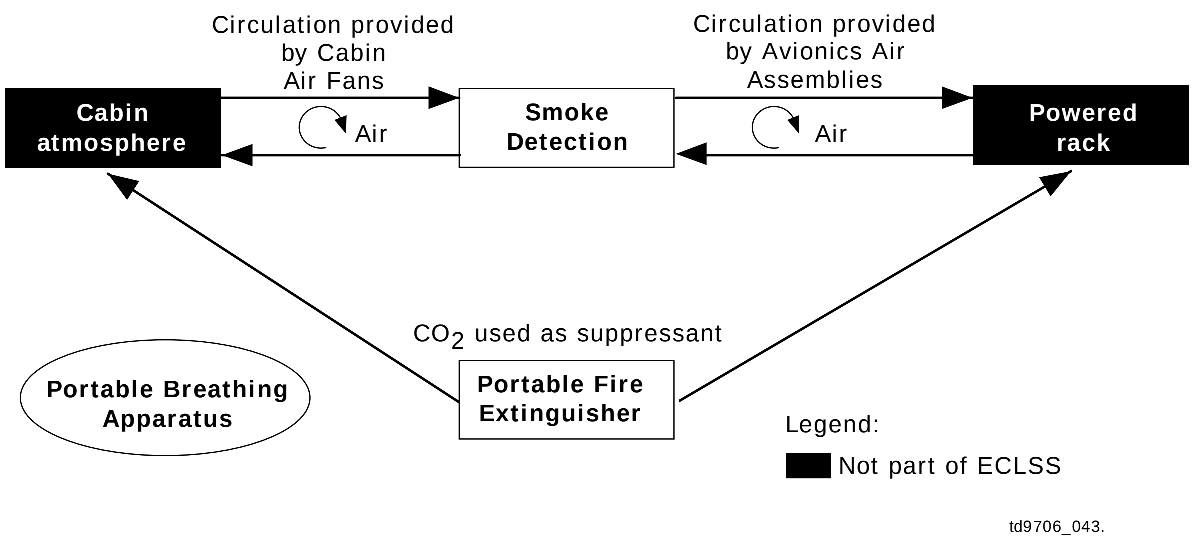

Figure 6-6. Fire Detection and Suppression Subsystem

6.3.4.1 Smoke Detectors

The FDS Subsystem provides two area Smoke Detectors in each pressurized module, as well as a Smoke Detector in each rack requiring an Avionics Air Assembly. These Smoke Detectors operate on a light-obscuration principle, and are mounted in THC Subsystem air paths. The ROS has two types of Smoke Detectors. One type is similar to USOS Smoke Detectors; the other is an ionization-type Smoke Detector.

6.3.4.2 Caution and Warning Panel

A Caution and Warning (C&W) Panel mounted in each USOS module features lighted emergency buttons. If smoke is detected, flight software will light the “FIRE” button, sound an alarm, and shut off THC equipment in the area to minimize oxygen being fed to the fire. Crewmembers may also sound (or silence) a fire alarm by manually pushing the button on the C&W Panel or on the PCS.

6.3.4.3 Portable Fire Extinguisher

Fires on the USOS can be extinguished with hand-held carbon dioxide-filled Portable Fire Extinguishers (PFEs). A PFE functions very similarly to a typical fire extinguisher here on Earth. Two different nozzles allow the PFE to be used on both open-area and rack fires. The ROS uses fire extinguishers filled with a non-toxic substance that can be dispensed as a foam or a liquid.

6.3.4.4 Portable Breathing Apparatus

During a fire, crewmembers must wear a Portable Breathing Apparatus (PBA), which is essentially a gas mask and an oxygen bottle. The PBA can also be plugged into oxygen ports provided by the Atmosphere Control and Supply Subsystem. The PBA is particularly important for a crewmember using the PFE, because carbon dioxide displaces oxygen in the vicinity (hence its effectiveness in fire suppression). This high concentration of carbon dioxide could cause the crewmember to lose consciousness if he or she is not supplied direct oxygen via a PBA.

6.3.4.5 Added FDS Capabilities at Assembly Complete

There are no functional differences between 8A and Assembly Complete; there will simply be more equipment available at Assembly Complete.

6.3.5 Water Recovery and Management

In Figure 6-7, the USOS Water Recovery and Management (WRM) Subsystem and its interfaces are illustrated for a Flight 8A configuration. WRM collects, stores, and distributes the Station's water resources. The water collected includes condensate from the Temperature and Humidity Control (THC) Subsystem and return water from EVA activities. Collected water is transported to the ROS for processing or vented overboard.

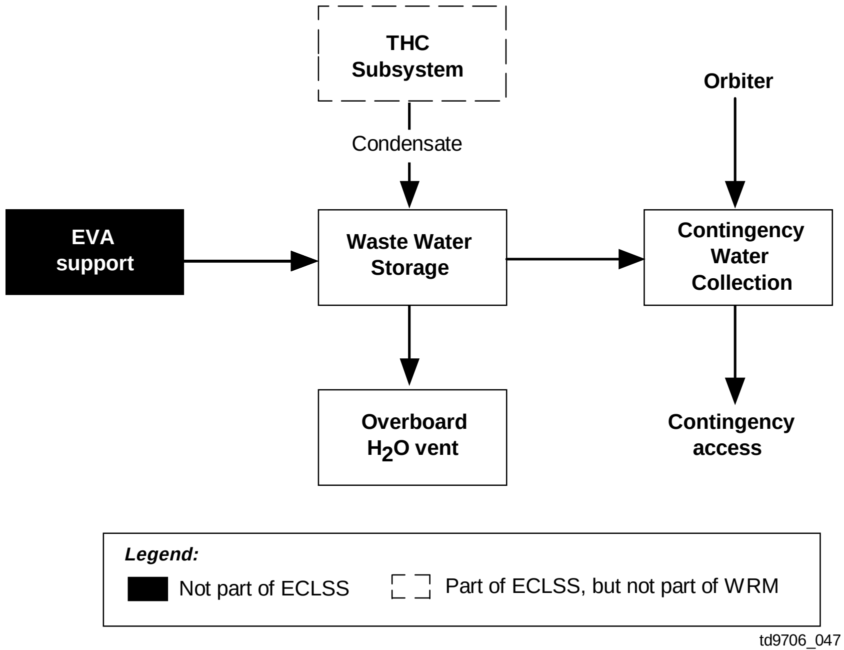

Figure 6-7. Water Recovery and Management Subsystem at Flight 8A

6.3.5.1 ROS WRM Overview

The WRM Subsystem on the ROS is primary for most of the assembly stages of the Station. The ROS collects condensate water from its condensing heat exchangers, as well as that manually transported from the USOS. This water can be purified using a purification column ( ), and is then monitored for quality in the . If the water is not good, it is stored for later reprocessing; if it is good, the water is passed through conditioning columns ( ) which make the water potable. If water is needed in the Elektron oxygen generator, the potable water must be repurified beforehand. Small tanks called are used to store and transport water in various locations on the ROS. Larger tanks with a pump assembly (Rodnik) store potable water both on the exterior of the Service Module and on Progress modules.

6.3.5.2 USOS Water Sources

At Flight 8A, the USOS collects condensate water from the THC Subsystem's Water Separator, as well as waste water from the Extravehicular Mobility Units (space suits). Waste water lines transport the water throughout the USOS.

6.3.5.3 USOS Water Storage

The waste water lines connect to a Condensate Tank. All USOS waste water is stored here until removed from the system.

6.3.5.4 USOS Water Disposal

Once the Condensate Tank fills, the water can be transferred to a Contingency Water Collection (CWC) assembly similar to a large gym bag and manually transported to the ROS for processing, or the water can be vented overboard through a series of valves and heaters called the Water Vent Assembly (WVA).

6.3.5.5 Added WRM Capabilities at Assembly Complete

Figure 6-8 is similar to Figure 6-7, but it depicts an Assembly Complete configuration of the USOS WRM Subsystem, after several capabilities are added. A network of fuel cell water lines and a Fuel Cell Water Tank will be used to transport and store water produced by the shuttle's fuel cells for use as make-up water on the ISS. A Urine Processor (UP) separates water from urine collected in the waste management compartment and refines it to waste water. A Potable Water Processor (PWP) then refines waste water (including condensate, fuel cell water, EVA waste water, and UP output water) into drinkable water, and the quality of the PWP product is monitored by a Process Control and Water Quality Monitor (PCWQM). Waste products from various sources are collected and put on a Progress module for incineration upon atmosphere reentry.

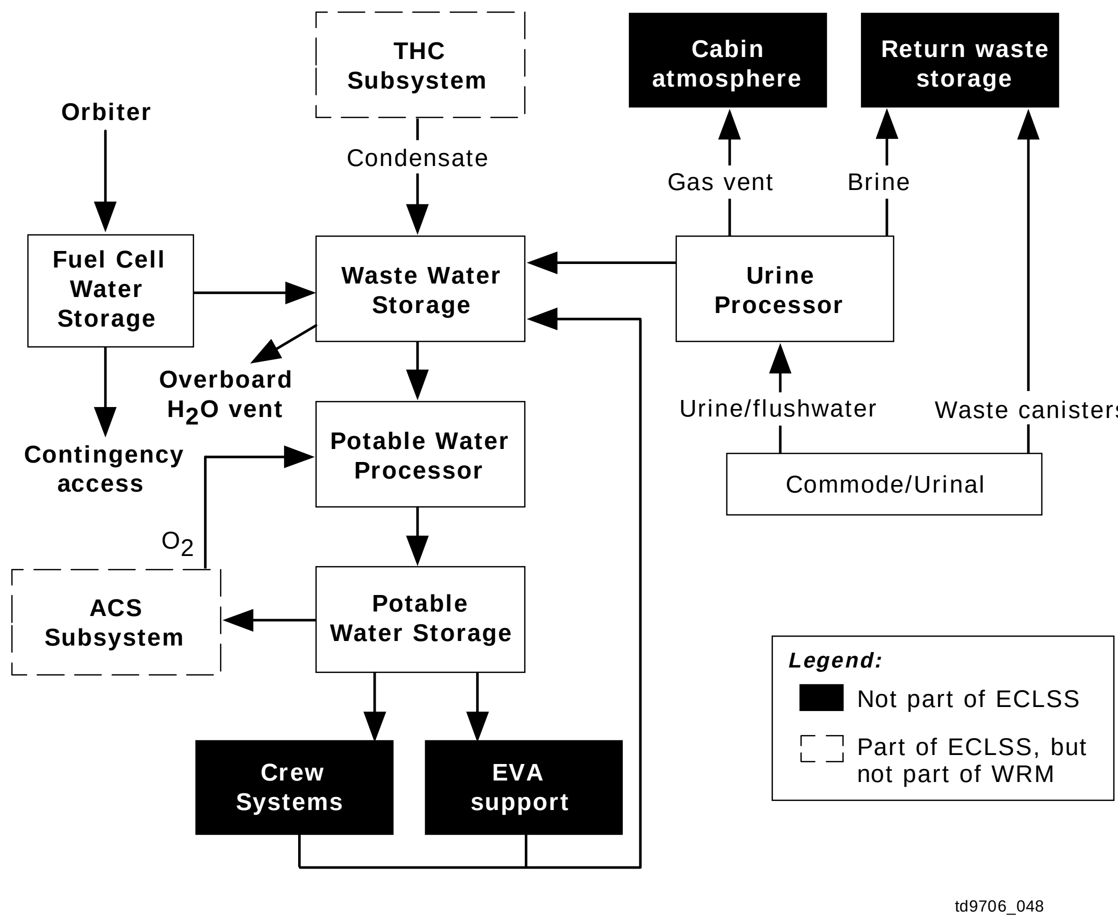

Figure 6-8. WRM Subsystem at Assembly Complete

6.4 ECLSS Interfaces

In Figure 6-9, the interfaces that ECLSS shares with other ISS systems at Flight 8A are illustrated. At Assembly Complete, potable water will also be provided to Crew Systems and to EVA Systems.

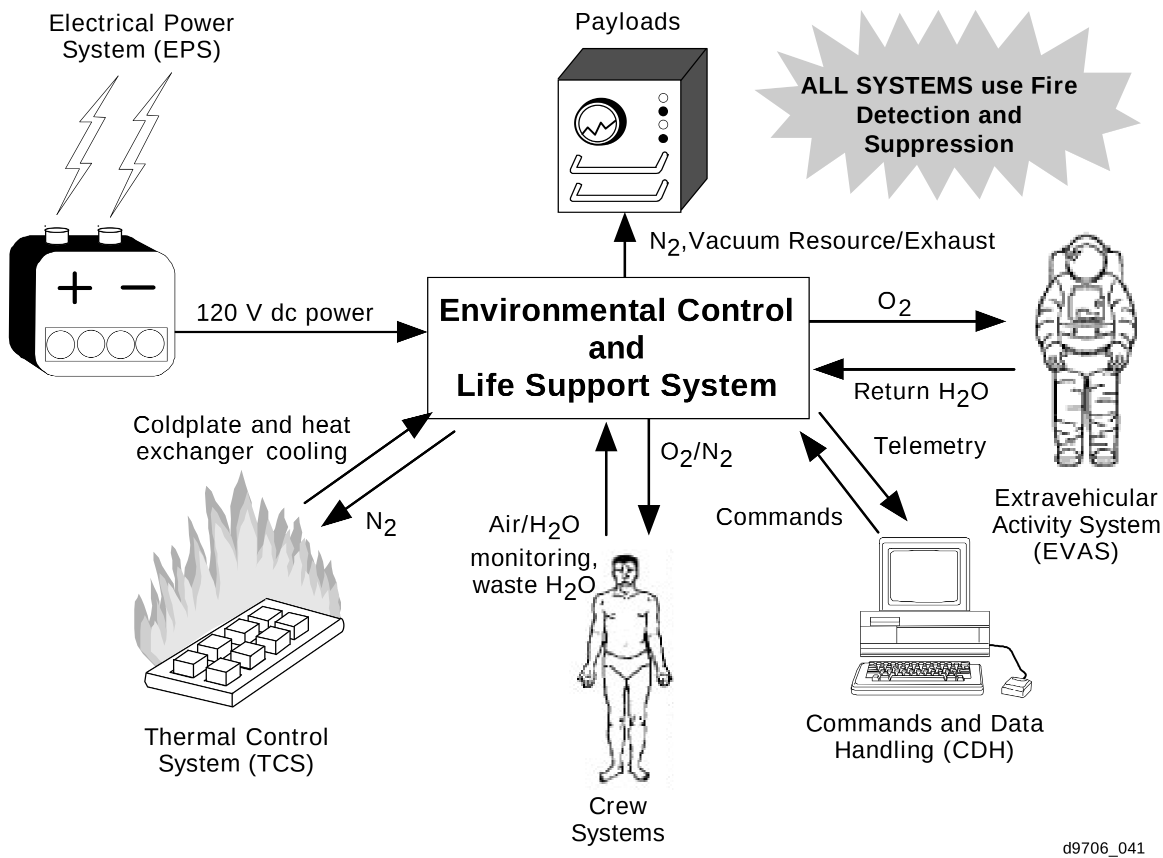

Figure 6-9. ECLSS interfaces at Flight 8A

6.5 ECLSS Milestones

There are several important milestones in the buildup of ISS ECLSS. Because ECLSS is primarily concerned with the maintenance of living conditions, these milestones correspond to the arrival of pressurized modules.

6.5.1 Flight 1A/R - Functional Cargo Block

The FGB is the foundation module of the ISS. It contains the first few pieces of ECLSS equipment, including circulation fans and non-condensing atmospheric heat exchangers, fire detection and suppression equipment, and a Gas Analyzer.

6.5.2 Flight 2A - Node 1

At Flight 2A, Node 1 and two Pressurized Mating Adapters (PMAs) are delivered to the Station. Node 1 contains a Cabin Air Fan, IMV equipment, and a Cabin Pressure Sensor, as well as FDS equipment and MPEVs on each hatch.

6.5.3 Flight 1R - Service Module

Most of the Russian ECLSS equipment on the Station at Flight 8A is housed in the Service Module. This includes the Elektron, carbon dioxide and contaminant removal devices, Gas Analyzers, fire detection and suppression equipment, air cooling and humidity removal equipment, urinal and commode facilities, and a condensate water processor. The arrival of the Service Module marks the beginning of the three-person permanent presence capability.

6.5.4 Flight 5A - Lab

Much of the USOS ECLSS equipment available during most of the assembly stages arrives with the Lab. ACS is provided with gas lines, PCA, VRA, and MPEVs. A complete rack of AR equipment arrives, and the SDS lines launched in the Lab and Node 1 are connected to the MCA in the Lab. THC sees the arrival of two CCAAs and more IMV equipment, as well as AAAs in several racks. The standard FDS equipment is launched with the Lab, as are the WRM condensate tank, WVA, and waste and (unused) fuel cell water lines.

6.5.5 Flight 7A - Airlock

At Flight 7A, the Airlock is installed, along with much of the ACS storage and distribution equipment, more MPEVs, and another PCA. Another CCAA and more IMV equipment arrive, and SDS lines are hooked into the USOS-wide network. The standard FDS equipment is manifested, as is the Depressurization Pump. ***This flight marks the last major USOS ECLSS build-up until the arrival of Node 2.***

6.6 Summary

6.6.1 ECLSS Purpose and Functions

The Environmental Control and Life Support System (ECLSS) maintains a pressurized habitable environment, provides water recovery and storage, and provides fire detection and suppression within the ISS.

6.6.2 Subsystem Names and Functions

There are five major subsystems within ECLSS

- Atmosphere Control and Supply (ACS) provides oxygen and nitrogen to maintain the Station atmosphere at the correct pressure and composition for human habitation. ACS also provides gas support to various users on the Station, as well as pressure equalization and depressurization capabilities.

- The Atmosphere Revitalization (AR) Subsystem ensures that the atmosphere provided by ACS remains safe and pleasant to breathe. AR performs carbon dioxide removal, trace contaminant control, and major atmospheric constituent monitoring.
- Temperature and Humidity Control (THC) helps maintain a habitable environment by circulating air, removing humidity and particulates, and maintaining the temperature of the Station atmosphere. Three levels of circulation are provided: rack, intramodule, and intermodule ventilation.
- The Fire Detection and Suppression (FDS) Subsystem provides smoke detection sensors for the Station volumes, fire extinguishers, and a system of alarms and automatic software responses to a fire event.
- The Water Recovery and Management (WRM) Subsystem collects, stores, and distributes the Station's water resources.

6.6.3 Milestones

There are three major milestones in the buildup of USOS ECLSS capabilities. On Flight 2A, Node 1 contains the first set of ECLSS equipment, consisting principally of ventilation and FDS equipment. Next, on Flight 5A, the Lab module carries a majority of the U.S. ECLSS equipment to be discussed in this manual, including major portions of all subsystems. Finally, on Flight 7A in the Airlock, the full capabilities of ACS are enabled, and additional THC and FDS equipment ensures crew health and comfort during EVA operations.

Questions

1. The Atmosphere Revitalization (AR) Subsystem is primarily responsible for
   a. Adding oxygen and nitrogen into the cabin atmosphere
   b. Circulating atmosphere throughout the Station
   c. Removing contaminants from the cabin atmosphere
2. At Flight 8A configuration, the Station’s oxygen supply is provided by the oxygen generator in the Russian segment. Which of the following is NOT available as a backup oxygen supply?
   a. The oxygen generator in the Lab
   b. Solid fuel oxygen generator in the Service Module
   c. The oxygen tanks stored outside the Airlock
3. The function of the USOS Water Recovery and Management (WRM) Subsystem is to
   a. Provide cooling using a Condensing Heat Exchanger
   b. Provide collection, storage, and venting of condensate water

c. Provide potable water for the crew before Assembly Complete

4. Which module contains two CCAAs?

   a. Lab

   b. Node 1

   c. Airlock

5. What subsystem's equipment depends on THC air circulation to operate properly?

   a. Fire Detection and Suppression (FDS)

   b. Water Recovery and Management (WRM)

   c. Atmosphere Control and Supply (ACS)